EE 382 Applied EM Quiz #6 (Spring 2018)

Name Key A

Instructions: Closed book. Place answers in indicated spaces and **show all work for credit.**

Equations: $\gamma = \sqrt{j\omega\mu(\sigma + j\omega\varepsilon)} = \alpha + j\beta$, $u = f\lambda = \frac{\omega}{\beta}$, $\delta = \frac{1}{\alpha}$, $\eta = \sqrt{\frac{j\omega\mu}{\sigma + j\omega\varepsilon}}$, $\lambda = \frac{2\pi}{\beta}$, $\frac{|\bar{J}_c|}{|\bar{J}_d|} = \frac{\sigma}{\omega\varepsilon}$

In the mountains of Wakanda, a time-harmonic electromagnetic wave, oscillating at 440 MHz, is propagating through vibranium ore characterized by the parameters: $\sigma = 0.025$ S/m, $\mu_r = 5$, and $\varepsilon_r = 8$. Find the loss tangent, attenuation & phase constants, skin depth, wave velocity, and intrinsic impedance of the ore. **(EXPRESS ALL COMPLEX NUMBERS IN RECTANGULAR FORMAT)**

$\gamma = \sqrt{j\omega\mu(\sigma + j\omega\epsilon)} = \sqrt{j\,2\pi\,440\times10^6(5)\,4\pi\times10^{-7}(0.025 + j\,2\pi\,440\times10^6(8)\,8.8542\times10^{-12})}$

$= \underset{\text{(atten. const.)}}{3.7153622} + j\underset{\text{(phase const)}}{58.441486}\ m^{-1}$

$\delta = \frac{1}{\alpha} = \frac{1}{3.71536} = 0.26915\ m$ (skin depth)

$\frac{\sigma}{\omega\epsilon} = \frac{0.025}{2\pi\,440\times10^6(8)\,8.8542\times10^{-12}} = 0.127664$ (loss tangent)

$u = \frac{\omega}{\beta} = \frac{2\pi(440\times10^6)}{58.4415} = 4.7305463\times10^7\ m/s$ (wave velocity)

$\eta = \sqrt{\frac{j\omega\mu}{\sigma + j\omega\epsilon}} = \sqrt{\frac{j\,2\pi\,440\times10^6(5)\,4\pi\times10^{-7}}{0.025 + j\,2\pi\,440\times10^6(8)\,8.854\times10^{-12}}}$

$\eta = 296.032525 + j18.819988\ \Omega$ (intrinsic impedance)

attenuation constant = 3.71536 Np/m phase constant = 58.44149 rad/m

skin depth = 0.26915 m loss tangent = 0.12766

wave velocity = 4.73055×10^7 m/s intrinsic imp. = $296.0325 + j18.8200\ \Omega$

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Name Key B

Instructions: Closed book. Place answers in indicated spaces and **show all work for credit.**

Equations: $\gamma=\sqrt{j\omega\mu(\sigma+j\omega\varepsilon)}=\alpha+j\beta$, $u=f\lambda=\frac{\omega}{\beta}$, $\delta=\frac{1}{\alpha}$, $\eta=\sqrt{\frac{j\omega\mu}{\sigma+j\omega\varepsilon}}$, $\lambda=\frac{2\pi}{\beta}$, $\frac{|\bar{J}_c|}{|\bar{J}_d|}=\frac{\sigma}{\omega\varepsilon}$

In the mountains of Wakanda, a time-harmonic electromagnetic wave, oscillating at 370 MHz, is propagating through vibranium ore characterized by the parameters: $\sigma = 0.022$ S/m, $\mu_r = 4$, and $\varepsilon_r = 7$. Find the loss tangent, attenuation & phase constants, skin depth, wave velocity, and intrinsic impedance of the ore. **(EXPRESS ALL COMPLEX NUMBERS IN RECTANGULAR FORMAT)**

$\gamma=\sqrt{j\omega\mu(\sigma+j\omega\epsilon)}=\sqrt{j\,2\pi\,370\times10^6(4)4\pi\times10^{-7}(0.022+j\,2\pi\,370\times10^6(7)8.8542\times10^{-12})}$

$= \underline{3.1235581} + j\,\underline{41.1523407}\ m^{-1}$

α (atten. const) $\quad\beta$ (phase const.)

$\delta=\frac{1}{\alpha}=\underline{0.320148\ m}$ (skin depth)

$\frac{\sigma}{\omega\epsilon}=\frac{0.022}{2\pi(370\times10^6)7(8.8541878\times10^{-12})}=\underline{0.152684}\equiv$ loss tangent

$u=\frac{\omega}{\beta}=\frac{2\pi(370\times10^6)}{41.1523407}=\underline{5.64920\times10^7\ m/s}$ (wave velocity)

$\eta=\sqrt{\frac{j\omega\mu}{\sigma+j\omega\epsilon}}=\sqrt{\frac{j\,2\pi(370\times10^6)4(4\pi\times10^{-7})}{0.022+j\,2\pi\,370\times10^6(7)8.8542\times10^{-12}}}$ (intrinsic impedance)

$= \underline{282.33326 + j\,21.42975\ \Omega}$

attenuation constant = 3.12356 Np/m phase constant = 41.15234 rad/m

skin depth = 0.32015 m loss tangent = 0.15268

wave velocity = 5.6492×10^7 m/s intrinsic imp. = $282.3333 + j\,21.42975\ \Omega$